FLOW GUIDE COMPONENT WITH ENHANCED COOLING

FIELD OF THE INVENTION

This invention relates generally to the field of internal to combustion engines and, more particularly, to a flow guide component that produces increased cooling effectiveness without producing reduced engine efficiency.

BACKGROUND OF THE INVENTION

Combustion engines are machines that convert chemical energy stored in fuel into mechanical energy useful for generating electricity, producing thrust, or otherwise doing work. These engines typically include several cooperative sections that contribute in some way to the energy conversion process. In gas turbine engines, air discharged from a compressor section and fuel introduced from a fuel supply are mixed together and burned in a combustion section. The products of combustion are harnessed and directed through a turbine section, where they expand and turn a central rotor shaft. The rotor shaft may, in turn, be linked to devices such as an electric generator to produce electricity.

To increase efficiency, engines are typically operated near the operational limits of the engine components. For example, to maximize the amount of energy available for conversion into electricity, the products of combustion (also referred to as the working gas or working fluid) often exit the combustion section at high temperature. This elevated temperature generates a large amount of potential energy, but it also places a great deal of stress on the downstream fluid guide components, such as the blades and vanes of the turbine section.

In an effort to help components within the engine withstand these temperatures, a number of strategies have been developed. One strategy is to manufacture these components from advanced materials that can operate in high-temperature environments for extended periods. Another strategy includes protecting the components with special, heat-resistant

coatings that lessen the effects of exposure to elevated temperatures. In still another strategy, the components may be cooled through a variety of methods. Each of these strategies has advantages and disadvantages, and the strategies may be combined to fit various situations and operating conditions.

In situations where turbine components are cooled, one cooling method involves delivering compressor-discharge air, or other relatively-cool fluid, to the exterior of the components. The cooling fluid may flow along the surface of the component, as in "film" cooling, or it may be guided to impinge upon the component surface. Cooling fluid may also be delivered to the interior of a component so that the component temperature may be reduced from the inside out.

Although cooling may be used to improve the high-temperature operation of blades and vanes, problems associated with this strategy limit its effectiveness in many situations. In situations where the cooling fluid is air provided by the compressor, extensive use of cooling may adversely affect engine performance by reducing the amount of air available for combustion and reducing power generating capacity of a given engine. Even in situations where cooling fluid is not provided by the compressor, it is difficult to ensure that all components are cooled sufficiently. Inadequate cooling can be troublesome, because in cases where portions of a component are not cooled sufficiently, the component may fail during operation.

While a variety of strategies have been developed to improve the high-temperature tolerance of turbine engine components, there are difficulties associated with these strategies. Additionally, as performance requirements increase, turbine components are subjected to even-more-extreme conditions. Accordingly, there remains a need in this field for strategies that allow turbine engine components to withstand extreme temperatures.

Summary of the Invention

The present invention is a turbine engine flow guide component that provides improved tolerance to extreme operating temperatures. The guide component includes features that allow highly-efficient cooling and increased heat dissipation properties. The component includes an elongated body having an interior cavity that includes cooling fluid flowpath. First and second guided-flow regions in the flowpath are separated by a contoured boundary member. The first guided-flow region is substantially surrounded by the boundary member and adapted to produce a vortex of cooling fluid. The second guided-flow region is disposed between an end of the cavity and an outer surface of the boundary member. The first guided-flow region is adapted to cool a region surrounded by the boundary member, and the guided-flow region is adapted to cool the region disposed between the cavity and outer surface of the boundary member, thereby ensuring effective cooling of the component without requiring increased cooling flow volume or producing overcooled areas.

Other advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings wherein are set forth, by way of illustration and example, certain embodiments of this invention. The drawings constitute part of this specification and include exemplary embodiments of the present invention and illustrate various objects and features thereof.

Brief Description of the Drawing

Fig. 1 is a side plan view of an engine using the fluid guide component of the present invention;

Fig. 2 is a cross-section end view of the fluid guide component shown in Fig. 1, taken along cutting plane II-II' therein;

Fig. 3 is close up view of the image shown in Fig. 2

Fig. 4 is partial isometric view of the fluid guide component of the present invention; and

Fig. 5 is an alternate close up view of the image shown in Fig. 2, showing fluid flow.

Detailed Description of the Invention

Reference is made to the Figures, generally, in which a fluid guide component 10 according to the present invention is shown. By way of overview, the guide component 10 includes elements that allow the component to provide enhanced temperature reduction without reducing engine performance. In one aspect of the invention, the fluid guide component 10 includes an interior cavity 18 having features that increase heat dissipation without relying on an increased volume of cooling fluid flow. In another aspect of the invention, the guide component 10 includes guided-flow regions 28,30 that strategically direct cooling fluid 20 through the component interior cavity 18, thereby ensuring key areas of the component 10 are cooled appropriately. In yet another aspect of the invention, the fluid guide component 10 includes structure that ensures effective cooling of an interior cavity turning zone 48 without producing overcooled regions within the component.

With particular reference to Figures 1 and 2, a first embodiment of a fluid guide component 10 of the present invention will now be discussed. In this embodiment, the component 10 is an internally-cooled turbine blade for use in a combustion engine 12. Accordingly, the component 10 is characterized by an attachment end 44 spaced apart from an opposite blade tip end 54 by an elongated body portion 16. The elongated body portion 16 has an airfoil-shaped cross section with a leading edge 66 spaced apart from an opposite trailing edge 68 by substantially-continuous, opposing sidewalls 70,72. It is noted that the guide component 10 need not be a blade; other embodiments, including stationary vanes or other internally-cooled, fluid-directing elements may also be used and are contemplated by this invention.

With continued reference to Figure 2, and with additional reference to Figure 4, the body portion 16 of the fluid guide component 10 has an interior cavity 18 with partition members

22,24 disposed therein. The partition members 22,24 extend between the body portion sidewalls 70,72 and cooperate with boundary surfaces 58,60,62,64 of the interior cavity 18 to define a cooling fluid flowpath 26 characterized by three channels 34,36,37. First and second turning zones 48,56 located within the interior cavity 18 near the tip end 54 and attachment end 44, respectively, each fluidly link an associated pair 34,36 and 36,37 of cooling channels. During operation, cooling fluid 20 is directed through the flowpath 26 to remove heat from the component 10. At least one cooling fluid inlet 40 allows cooling fluid 20 to enter the interior cavity 18, and cooling fluid outlets 42 allow the cooling fluid to exit. Although Figure 2 shows the attachment end 44 of the blade 10 as the cooling fluid inlet 40 location, cooling fluid 20 may enter the interior cavity 18 from other locations if desired.

With reference to Figures 2 and 3, the first turning zone 48 will now be described. As noted above, the first and second channels 34,36 are fluidly linked by a first turning zone 48, and a contoured boundary member 32 divides the first turning zone into two guided-flow regions 28,30. These guided-flow regions 28,30 cooperatively ensure that the first turning zone 48 is cooled appropriately. More particularly, as seen with reference to Figures 3 and 5, each region 28,30 directs a portion 50,52 of cooling fluid through a key area of the first turning zone 48: a first portion 50 of cooling fluid 20 flows through the first guided-flow region 28 to reduce the temperature of the area adjacent the first partition member free end 38, and a second portion 52 of cooling fluid flows through the second guided-flow region 30 to reduce the temperature of the area between the contoured boundary member 32 and the cavity boundary surfaces 58,60,62 located at the tip end 54 of the component 10. As will be described more fully below, this dual guided-flow region arrangement advantageously ensures that the tip end 54 of the fluid guide component 10 is cooled as needed, without producing overcooled regions.

Now, with particular reference to Figures 3 and 4, a first embodiment of the contoured boundary member 32 will be described in detail. In this embodiment, the contoured boundary member 32 is an elongated component that extends between the body portion sidewalls 70,72.

With continued reference to Figure 4, the contoured boundary member 32 is a substantially-tubular structure with a cross section that resembles a horseshoe, including a rounded head portion 74 and a tapered shoulder portion 76. The head portion 74 provides a swirl-inducing region 94 which has a substantially-circular cross section characterized by a defining dimension D_{si}; the shoulder portion 76 defines a longitudinally-extending flowthrough passageway 46 characterized by a first lip 82 disposed within the first channel 34 and a second lip 84 disposed within the second channel 36.

As seen in Figures 3, 4 and 5, the first partition member 22 divides the flowthrough passageway 46 into an entrance region 49 and an exit region 80. The shoulder region first lip 82 and first partition member 22 are spaced apart by a distance D_i, and the shoulder region second lip 84 is spaced apart from the first partition member by a distance of D_e. It is also noted that the first partition member free end 54 need not be centered within the flowthrough passage 46: the values of D_i need not be equal D_e. In this embodiment, the ratio of D_i to D_e is about two. The entrance region 49 provides a metering slot through which the first portion 50 of cooling fluid enters the head portion 74, and the exit region allows cooling fluid to travel out of the head region and into the second channel 36, downstream of the first turning zone 48. The entrance and exit regions 49,80, along with the swirl-inducing region 94 form the first guided-flow region 28. These three regions 49,80,94 are fluidly linked and, as will be described more fully below, cooperatively form a cyclone or vortex of cooling fluid 50 within the swirl-inducing region that advantageously cools the region adjacent the first partition member free end 38. It is noted that the vortex flow pattern produced in the swirl-inducing region 94 increases the heat dissipation properties for the first portion 50 of cooling fluid passing adjacent the first partition member free end 38.

With continued reference to Figure 3, and with additional reference to Figures 4 and 5, as the first the first lip 82 and first partition free end 38 cooperatively direct the first portion 50 of cooling fluid along a path which is substantially-tangential to the vortex maintained by the

contoured boundaries of the swirl-inducing region 94. The interaction of fluid passing leaving the fluid entrance region 49 and entering the swirl-inducing region 94 creates a jet and contributes to the vortex flow established in the swirl-inducing region. Although the dimensions D_{si} and D_i may be scaled to accommodate fluid guide components 10 of various sizes, it is preferable that the ratio of D_{si} to D_i be within the range of about 10 to about 15. It is noted that while described as resembling a horseshoe, the contoured boundary member 32 may have a variety of cross-section profiles, including substantially C-shaped or U-shaped; essentially any cross section which forms a vortex or induces swirled flow within the first guided-flow region effective to reduce the temperature of the area adjacent the first partition member free end 38 would suffice and is contemplated by the present invention.

The second guided-flow region 30 will now be described in detail. As seen with in Figures 3 and 5, the second guided-flow region 30 extends between the outer surface 96 of the contoured boundary member 32 and the first, second, and third boundary surfaces 58,60,62 of the interior cavity 18. The relative spacing between the boundary surfaces 58,60,62 and the adjacent portion of the contoured boundary member outer surface 96 varies with position along the second guided-flow region 30. The second guided-flow region 30 comprises a first leg 98, a second leg 100, and a third leg 102; the legs are in fluid communication.

With cooperative reference to Figures 3 and 5, the first leg or section 98 spans flow-wise between the contoured boundary member first lip 82 and a first cavity tip end corner 86. The second leg or section 100 spans flow-wise between the first cavity tip end corner 86 and a second cavity tip end corner 88. The third leg or section 102 spans flow-wise between the second cavity tip end corner 88 and the contoured boundary member second lip 84. As noted above, The distance D_{sgf} between the contoured boundary member outer surface 96 and associated cavity boundary surface 58,60,62 varies with position along the second guided-flow region 30 and is strategically selected to impart desired flow characteristics to the second portion of cooling fluid 52 at key locations of the component 10. For example, the second

guided-flow region 30 is relatively-narrow near the cavity tip end corners 86,88, while remaining relatively broad near the first lip 82 and second lip 84.

With this arrangement, the second portion of cooling fluid 52 accelerates as it travels along the first leg 98 toward the first cavity tip corner 86, changes direction and continues accelerating along the second leg 100 toward the second cavity tip corner 88, changes direction once again and continues with decreasing velocity along the third leg 102 to head toward the second channel 36. In keeping with various aspects of the present invention, the second portion of cooling fluid 52 provides impingement cooling of the cavity tip corners 86,88, as well as internal cooling of tip wall 14. It is noted that the acceleration and directional changes produces along this second guided-flow region 30 enhance the heat dissipation capabilities of the second portion of cooling fluid. It is also noted that turbulence-increasing structures 104, often referred to as "trip strips" or turbulators, may be used to further augment the heat transfer properties of cooling fluid if desired.

During operation of an engine 12 in which the fluid guide component of the present invention is installed, cooling fluid 20 travels from a cooling fluid source, such as a compressor 106 (shown in Figure 1), pump or other suitable source, and enters the component interior cavity 18 via at least one cavity inlet 40. The cooling fluid 18 enters the first channel 34 and begins to travel along the cooling fluid flowpath 46 described above. With continued operation, cooling fluid 20 travelling within the first channel 34 enters the first turning zone 48 and encounters the contoured boundary member first lip 82, which splits the cooling fluid 20 into a first portion 50 and a second portion 52.

The behavior, path, and purpose of each portion 50,52 of cooling fluid is different and strategically selected to provide appropriate cooling to the guided-flow regions 28,30. With reference to Figures 3 and 5, the first portion 50 of cooling fluid travels into the first guided-flow region 28, and the second portion travels into the second guided-flow region 30. As noted above, the first guided-flow region 28 cools the region adjacent the first partition member free

end 38, while the second guided-flow region 30 cools the cavity tip corners 86,88 and the tip wall 14. Additionally, the exit region 80 of the first guided-flow path advantageously cooperates with the third leg 102 of the second guided-flow path 30 to ensure that flow separation tendencies are reduced as the first and second portions 50,52 of cooling fluid rejoin when leaving the first turning zone 48 to enter the second channel 36 and continue through the downstream remainder of the flowpath 26. After travelling through the cooling fluid flowpath 26, the cooling fluid 20 exits the component cavity 18 through a cavity outlet 42. With this arrangement, cooling fluid 20 travelling through within the internal cavity strategically cools the first turning zone 48 without an increased amount of cooling fluid volume or producing overcooled locations.

It is noted that the volume V_1 of the first portion 50 of cooling fluid flowing through the first guided-flow region 28 and the volume V_2 of the second portion 52 of cooling fluid flowing through the second guided-flow region 30 need not be equal. One particularly-effective ratio of V_2 to V_1 is within the range of about one to about four; that is, where volumetric flow in the second guided flow region 30 is up to about four times as much as the volumetric flow in the first guided flow region 28. It is also noted the cross sectional areas of the various regions have particularly-effective relationships in the present embodiment. For example, the ratio of cross-sectional area at the first cavity tip end corner 86 to the cross-sectional area at the beginning of the first guided-flow region 30 is within the range of about 0.65 to about 0.45. The ratio of cross-sectional area at the second cavity tip end corner 88 to the cross-sectional area at the end of the first guided-flow region 30 is within the range of about 0.65 to about 0.45. The ratio of cross-sectional area within the second guided flow region second leg 100 to the cross-sectional area at the first cavity tip end corner 86 is within the range of about 0.65 to about 0.80.

It is to be understood that while certain forms of the invention have been illustrated and described, it is not to be limited to the specific forms or arrangement of parts herein described and shown. It will be apparent to those skilled in the art that various, including modifications,

rearrangements and substitutions, may be made without departing from the scope of this invention and the invention is not to be considered limited to what is shown in the drawings and described in the specification. The scope if the invention is defined by the claims appended hereto.